Ground Penetrating Radar (GPR)

A Tool for Subsurface Utility Engineering

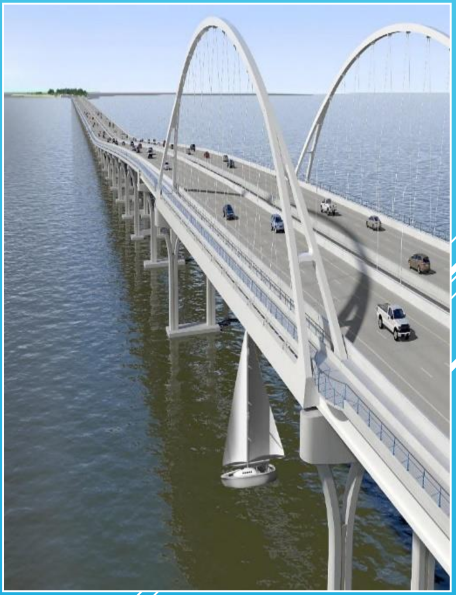
Alabama Pipeline Safety Seminar – December 2017

Presentation by

Jack Morrisroe, Staff Geophysicist/GPR

INTRODUCTION

- **Jack Morrisroe – Staff Geophysicist/GPR**
- **BHATE was founded in 1975**
  - **Offices in Alabama, Mississippi and Florida**
  - **Geotechnical and Geophysics services since 1970's**
  - **GPR services since 1995.**
  - **SUE services since 2004.**
  - **Dedicated engineers and GPR specialists**
  - **Current SUE contracts with ALDOT and MDOT**



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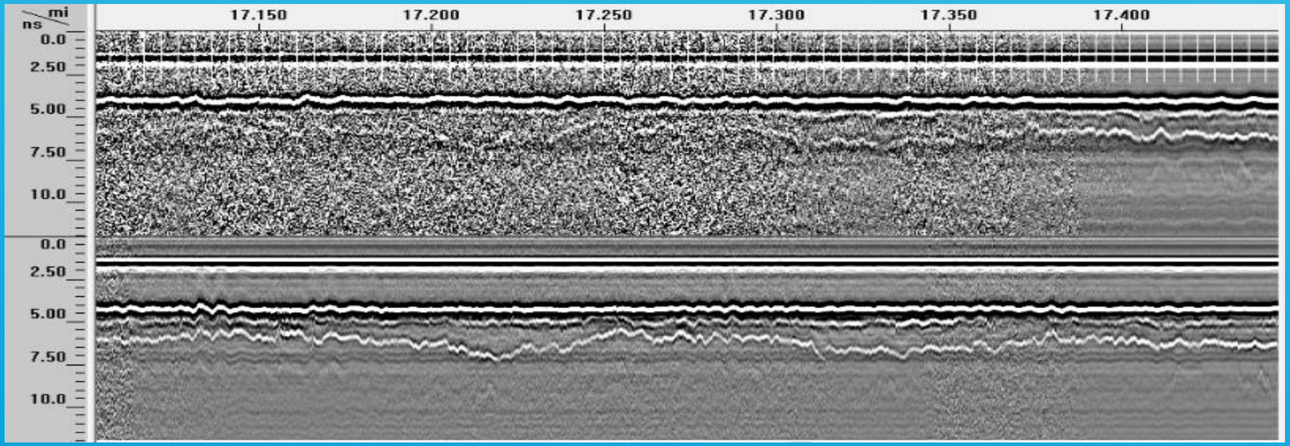
OBJECTIVES AND TOPIC DISCUSSION

- Introduction to the basic principles of GPR
- Capabilities and limitations
- Introduction to Subsurface Utility Engineering
- Bhate Project Examples

History of GPR

- 1910 - GPR was first patented
- 1960's and 1970's – GPR rapidly developed for military applications
  - Vietnam war – locating Viet Cong tunnels
- First commercially available units appeared in 1975
- Most recently
  - Systems operate faster due to developments in computer processing power (More data, higher quality data)
  - Background noise reduction



BASIC PRINCIPLES OF GPR

Limitations - Transmitting Frequency

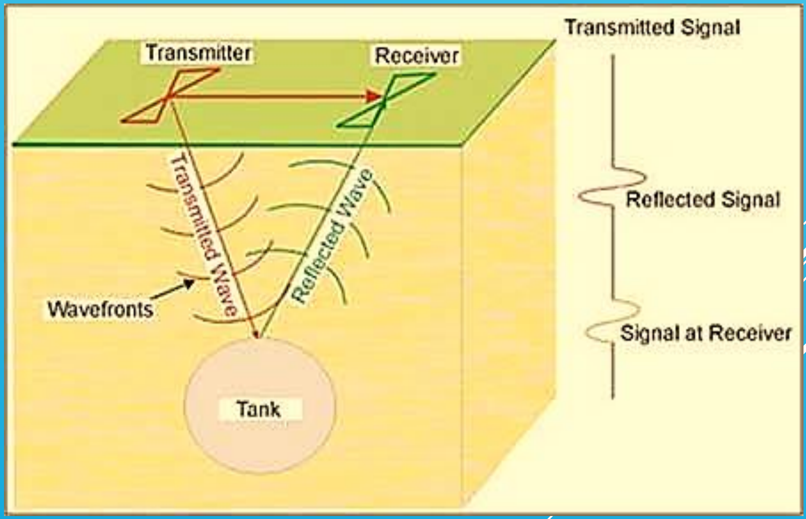
- GPR uses high-frequency radio waves.
- Due to the phenomenon of geometric spreading of transmitted energy, the minimum size for a feature to be detected must also increase with depth.
- Higher frequency antennas, will penetrate to shallower depths, but provide a higher resolution than their lower frequency counterparts.

How deep can GPR go into ground?:

It depend upon two condition:

- The type of soil or rock in the GPR survey area.
- The frequency of the antenna used.
  - Low frequency systems are more penetrating but data resolution is lower.
  - High frequency systems have limited penetration but offer a much higher resolution.

Antenna Frequency	Maximum Penetration Depth	Appropriate Application
1500 MHz	0.5 m	Rebar mapping and concrete evaluation.
900 MHz	1 m	Pipe and void detection or assessing concrete thickness.
400 MHz	4 m	Utility surveys, pavement evaluation, storage tank detection and assessing structural integrity
270 MHz	6m	Utility surveys, geology and archaeology



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TRADITIONAL GPR APPLICATIONS

- **Structural Scanning** - **Mapping rebar, PT Cable, conduit etc. in concrete and providing concrete slab thickness.**

- **Forensics** – **Floor slab settlement, structural failure evaluations**

- **Pavement and Bridge Deck assessment**

- **Geotechnical, Environmental and Archeological applications**

- **Subsurface Utility Engineering (SUE)** – **Location and depth of subsurface utilities.**

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What is Subsurface Utility Engineering (SUE)?

The lack of reliable underground utility information has long been a troublesome problem for designers in the United States. -FHWA

SUE is an Engineering Practice that involves:

- **Accurate Utility Mapping and Coordination**
- **Utility relocation design and adjustment through conflict resolution with cost/time considerations**
- **End Objective:**
  - **Time and cost savings plus better design**
  - **Reduce risk of damage to life and property**

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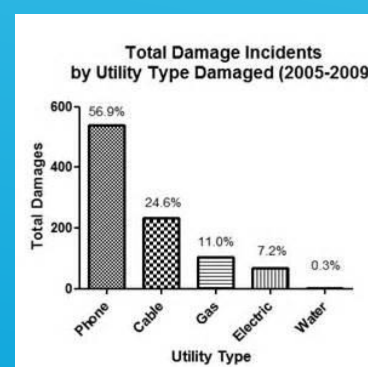
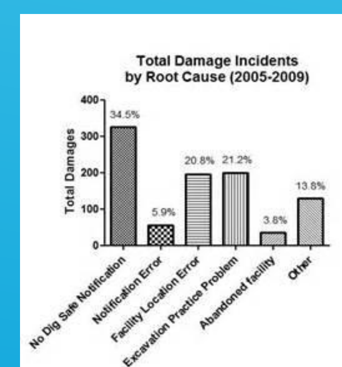
BACKGROUND AND SUE STANDARDS

- **The American Society of Civil Engineers (ASCE) developed:**
  - **National Consensus Standard titled *ASCE C-I 38-02*, *Standard Guidelines for the Collection and Depiction of Existing Subsurface Utility Data* also known as 'Subsurface Utility Engineering Services'. SUE**
  - **ASCE committee members were represented by governmental agencies, engineering profession, construction profession, academia, and project owners.**
- **American National Standards Institute (ANSI) accepted.**
- **The process allows the owner, engineer, and contractor to develop strategies to reduce risk and to allocate risk due to existing subsurface utilities in a defined manner.**





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BACKGROUND INFORMATION

- The Federal Highway Administration has been encouraging the use of Subsurface Utility Engineering on Federal-aid highway projects for the past 20+ years.

- The Legal System holds the ASCE National Consensus Standards in high regard.

- Courts use these standards to assist in defining a ‘standard of care’.

Did I do that ??

- *IMPORTANT TO UNDERSTAND LIMITATIONS*

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AN ESSENTIAL CONSIDERATION -SAFETY

- **Every year there are thousands of incidents involving contractors and accidental strikes to underground utilities.**

- **Inadvertent damages to buried utility lines while performing intrusive activities cost millions of dollars, but also could result in severe harm or even death to employees and innocent bystanders.**

- **As the network of underground utilities continues to increase, the contractor's risk of inadvertently damaging one of these lines also increases.**

- **Make Informed Design Decisions**
  - **Designers require accurate utility information, including constructability of multi-phase projects.**
- **Avoid Using Unreliable Underground Utility Information**
  - **Avoid uncertainty and second guessing where a utility may be located.**

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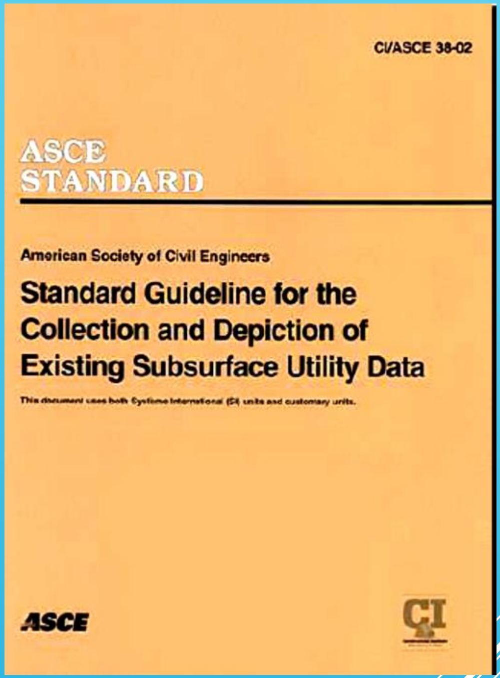
BASIS OF SUE WORK

- **FHWA-Utility Relocation and Accommodation on Federal-Aid Highway Projects- January 2003**
  - ***Provides Guidelines and Basis for:***
    - **Utility Accommodation**
    - **Utility Relocations, Adjustments and Reimbursements**
    - **Communication of Utility Data**
    - **Risk and Impact Analysis**
    - **Cost Estimate Procedures**
    - **Other Issues**



- **ASCE Standard CI/ASCE 38-02**
  - ***Quality Levels in Subsurface Utility Engineering as a Basis for:***
    - **Accurate Knowledge of Horizontal and Vertical Location**
    - **Data Management and Depiction of Utilities on Construction Plans Prior to Excavation**
    - **Design Around Underground Utilities to Avoid Costly Relocations**

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PROCEDURE FOR ACCOMPLISHING FIELD WORK GENERAL OUTLINE

- **Four (4) main utility data quality levels per ASCE CI 38-02**
- **Utility Quality Levels**
  - **QL-D**
  - **QL-C**
  - **QL-B**
  - **QL-A**

QL-B

Objective is to prevent this

QL-A – verification

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PROCEDURE FOR ACCOMPLISHING FIELD WORK

- **Records Research – QL-D**
  - **Gather and review available drawings and records. Meet with Utility Companies.**
  - **Get available as-built information**
  - **Preliminary assessment of the types of utilities present in the area and their likely location and depth.**

- **Initial Site Visit and Field Procedure – QL-C**
  - **Compare drawings to visible onsite conditions**
  - **Visually inspect available access points such as manholes for approximate depth and alignment of utilities present**
  - **Resolve discrepancies**

- **Determination of appropriate geophysical methods needed to designate or trace a particular utility system. Conduct field survey QL-B**

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Procedure for Accomplishing Field Work

This includes in-situ verification of utilities using GPR and other NDT methods

- **Geophysical Investigation- QL-B**
  - **Application of surface geophysical methods to determine the existence and position of utilities.**
    - **Ground penetrating radar (GPR)**
    - **Ferromagnetic Locators**
    - **RD 8000 cable and pipe locators**
    - **Other methods**
  - **One Call locating is used as a starting point**

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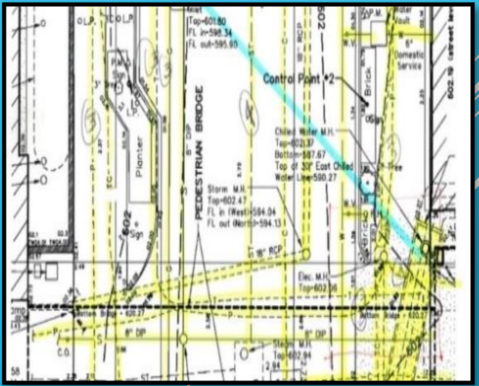
Procedure for Accomplishing Field Work – Level A

- **Actual Exposure – QL-A**
- ***This level is implemented in limited areas where Level B information is limited and high risk underground utilities require in-place exposure and verification of type and depths.***
  - **Highest level of accuracy available**
  - **Targetted nondestructive exposure of underground utilities**
  - **Minimally intrusive excavation equipment (vacuum extraction) to minimize the potential for utility damage**
  - **Type, size, depth, and location of utilities recorded and used to verify provided information**
  - **Depth of exposure can range from <3′ to 10′+**



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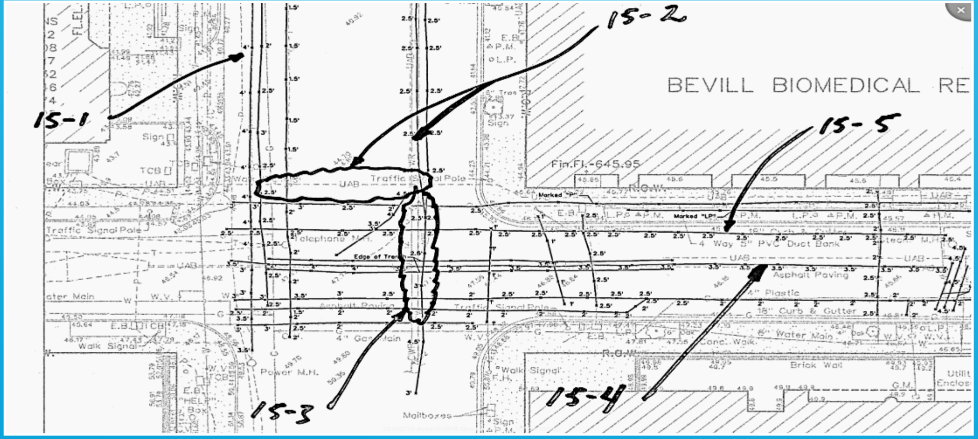
PROCEDURE FOR ACCOMPLISHING WORK DATA MANAGEMENT

- Upon completion of QL-B and QL-A, survey the alignment and depth. Deliverables include the following:
  - Plan/Profile sheets and Cross Sections showing utility locations.
  - Depict information using DOT Design Manual, CADD and Plan Preparation Standards.
  - Develop a conflict matrix showing all possible known utility conflicts with the proposed construction.
- Review potential conflicts with design team



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PROCEDURE FOR ACCOMPLISHING WORK IMPACT ASSESSMENT

- Where conflicts cannot be avoided and utilities will have to be relocated the following is generally required:
  - Follow FHWA Utility Relocation and Accommodation Guidelines
  - Perform a Risk and Impact Assessment
  - Review utility relocation options
  - Obtain relocation cost estimates from utility companies and other sources.
  - Submit deliverables

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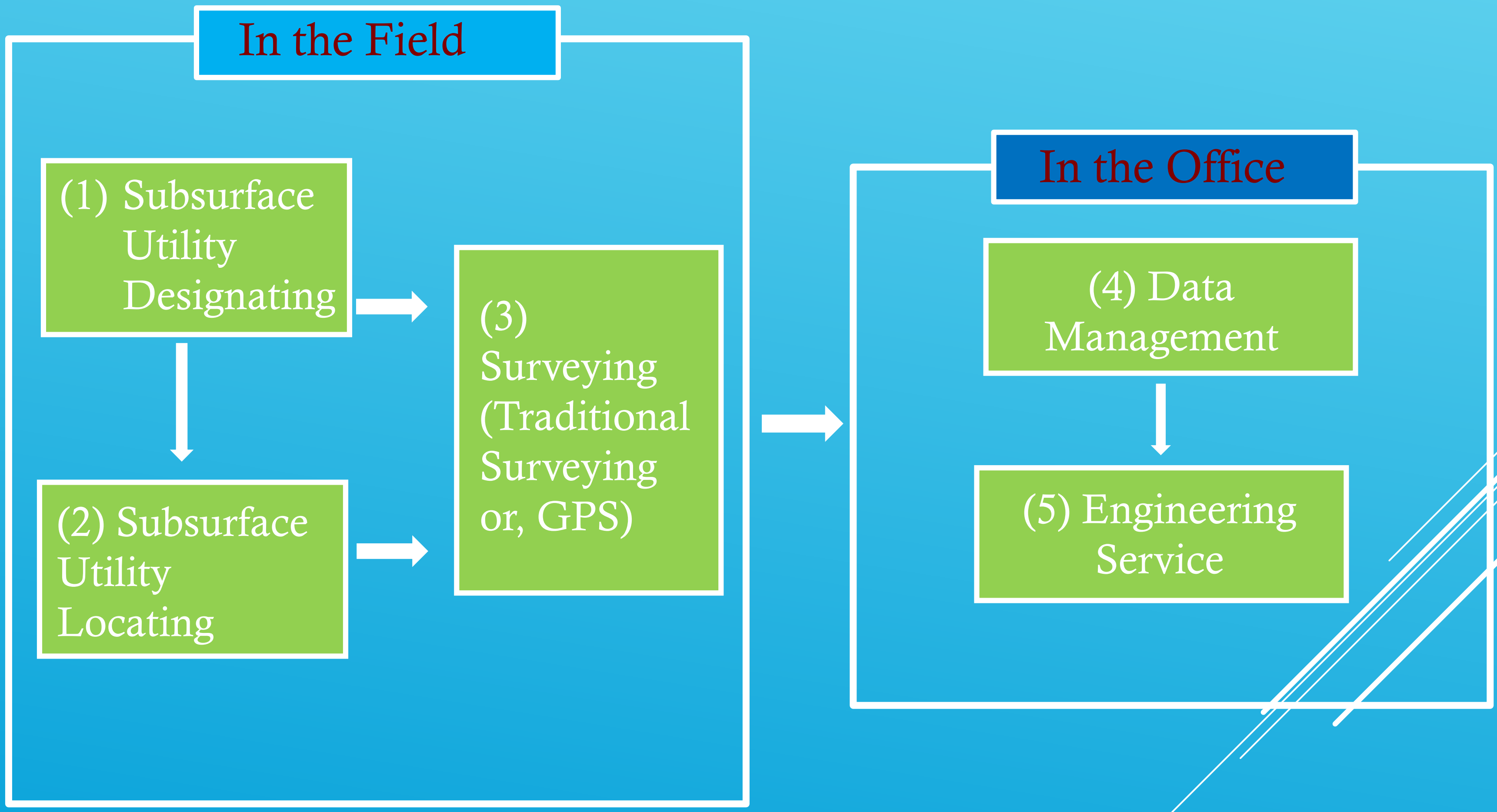
THE PROCESS



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SUE Level ‘B’ Field Equipment

Accurate Delineation of Utilities Requires a Combination of Methods

- ***Ground-Penetrating Radar*– Multiple antenna frequencies available.**
- **Vehicle Mounted GPR system**
- ***RD8000 cable and pipe locators and Tx transmitter***
- ***Ferro magnetic locators-* locating and pinpointing buried metal objects such as manholes and metallic pipes**

- ***Multiple methods are frequently used to validate the findings***

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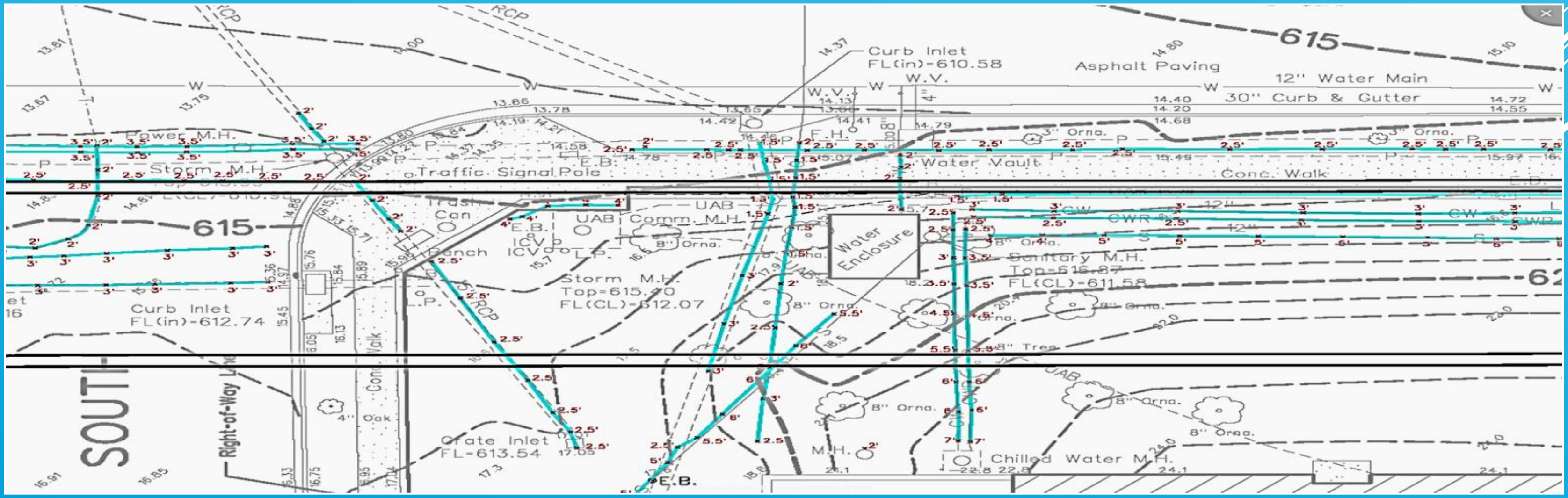
PROJECT EXAMPLES

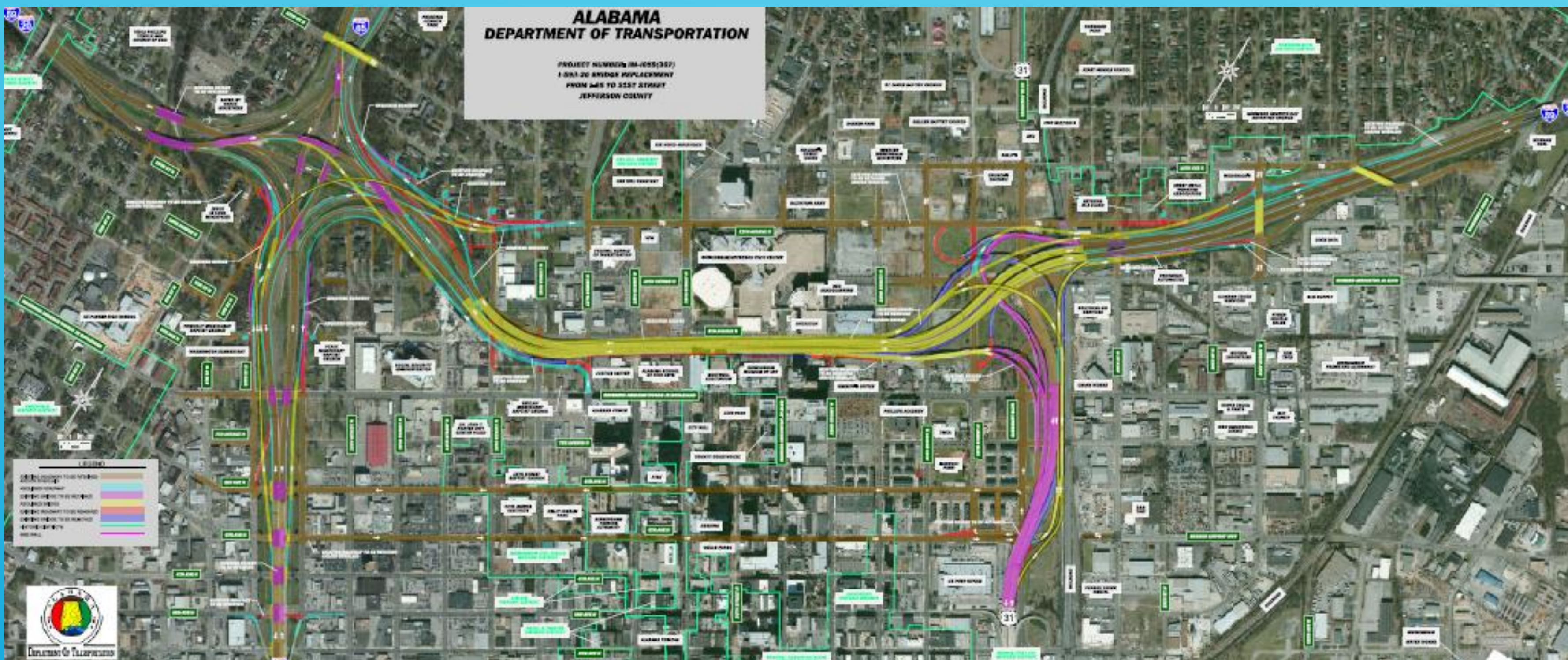
UAB DISTRICT STEAM SYSTEM PROJECT- BIRMINGHAM, AL

- **Utility mapping lasting 12 months, covering several miles of project alignment throughout the UAB campus and associated Medical Center and Academic Buildings.**
- **Located gas, water, communications, sewer and storm in densely congested urban conditions.**
- **Prepared plans, profiles and sections showing utility locations to QL-B.**
- **Select locations were exposed to QL-A for three dimensional verification.**
- **Prepared as-built drawings to determine the final alignment of the new steam line. Final project completed without any utility delays, damage or change orders. Client estimated that the process saved the project in excess of $2M**



PROJECT EXAMPLES

ALDOT CENTRAL BUSINESS DISTRICT BRIDGE PROJECT - BIRMINGHAM, AL



I-59/I-20 from I-65 to 31st Street
Birmingham, Alabama

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ALDOT - CBD PROJECT SUMMARY

- ALDOT is planning bridges along Interstate 59/20 through the City of Birmingham's Central Business District (CBD). Area commercially developed since 1880's.

- The work includes roadway and bridge widening on I-59/I-20 and I-65.

- Approximately 32 new bridges/ramps/bridge widening

- Improvements to the I-59/20/31st Street North interchange, and the I-59/20.US 31(Red Mountain Expressway) interchange are planned.

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UTILITY VERIFICATION PRIOR TO BORINGS

- **Geotechnical drilling included over 600 boring locations performed by multiple consultants including BHATE.**

- **It was necessary to verify that the proposed boring locations were free of subsurface utilities.**

- **This area consisted of gas, telephone, fiber-optic cables, high voltage electric and other sensitive targets that could be significantly impacted in case of damage during field exploration.**

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ALDOT - CBD BORING LOCATIONS

- BHATE provided pre-drilling SUE services to locate the utilities and clear boring locations to manage subsurface conflicts and reduce risk of potential damage.
- Of the 600 boring locations, nearly 17% of the borings were impacted by subsurface utilities and had to be shifted.
- Information available could not be accurately relied on

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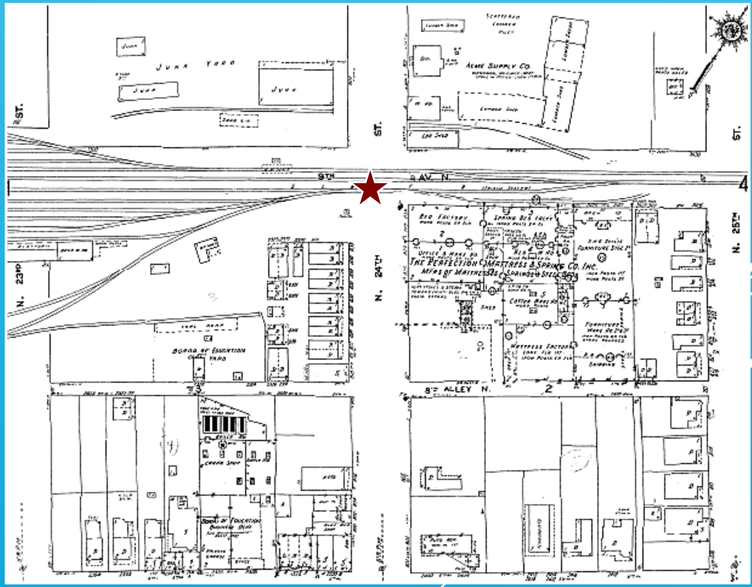
ALDOT SUE WORK - SITE SPECIFIC FINDINGS

- **QL-D and QL-C uncovered discrepancies**
  - **Historical records indicated old gas stations, a railroad yard with multiple tracks, oil refinery, dry cleaners, foundry, machine shop, storage yard, 25+ abandoned underground tanks were identified.**
  - **Utility records and surface features indicated that the drawings provided by utility companies did not accurately reflect in-ground conditions.**



SUE WORK - SITE SPECIFIC FINDINGS

- **QL-B investigation** **was performed to verify the location of buried utilities beneath proposed CBD bridge alignment.**
  - **Identified locations of buried railroad tracks. These were covered up by existing pavement with no visible signs on the surface.**
  - **Numerous undocumented underground utilities were found.**
  - **Discrepancies between utility drawings and actual locations were resolved.**
  - **Conflicts between actually existing utilities and proposed construction were identified.**

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ALDOT FEEDBACK

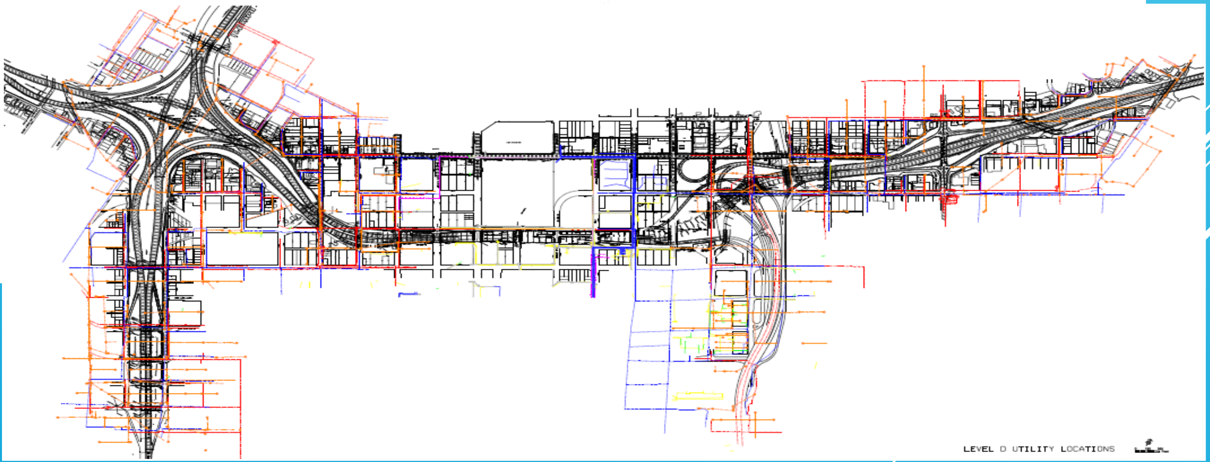
We called on Bhate Geosciences to perform Subsurface Utility Engineering on the project. We needed to accurately locate the underground utilities in downtown Birmingham. This information was used to help make a determination on where we could modify plans to eliminate utility conflicts and also to identify which ones would have to relocate.

The utility data was also useful not only to help the utilities in the project area update their company records and Geographic Information Systems with more accurate information on the location of their facilities, but also helped them purge old data where utilities that were shown on plans are no longer there. There were utilities shown on plans that we thought we would have to address, but the investigation eliminated those lines.

Sincerely,

Robert G. Lee

Robert G. Lee, P.E.
Acting ROW Engineer-Utilities



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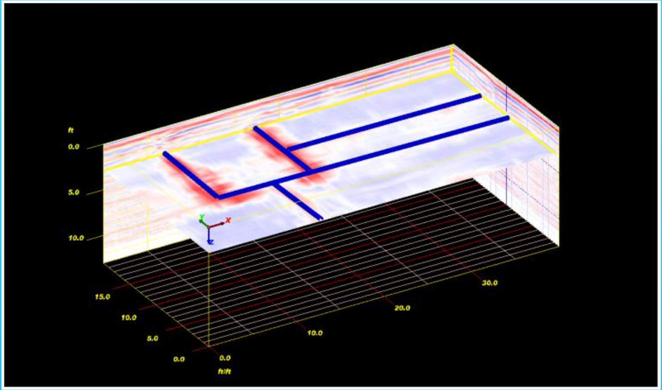
PROJECT EXAMPLES

GULFPORT SUBSURFACE INFRASTRUCTURE
KATRINA DAMAGE ASSESSMENT AND REPAIR

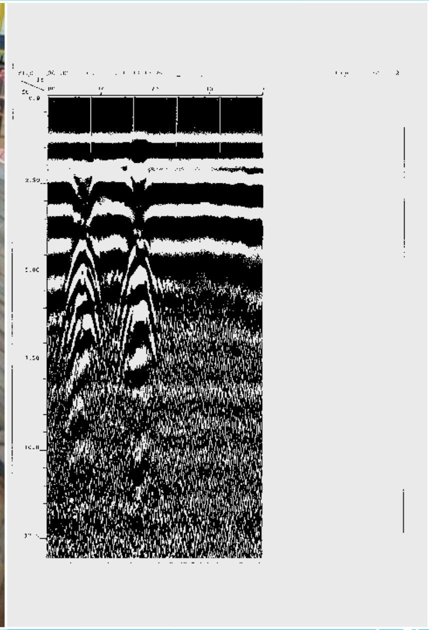
- **Gulfport FEMA Utility Mapping at 41 intersections to determine as-built locations and depths for post-Katrina reconstruction**
- **Located Gas, Water, Phone, Sewer, Storm, and Fiber Optics**
- **Prepared utility plan profile sheets showing utility locations, depths, types etc.**



SUE PROJECT EXAMPLES
CHILDREN'S HOSPITAL TUNNEL



3D image of utilities beneath the roadway with virtual pipes



6th Avenue South – GPR response from buried subsurface utility

6th Ave South – facing east along north curb line

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MDOT SUE Project- Highway 90

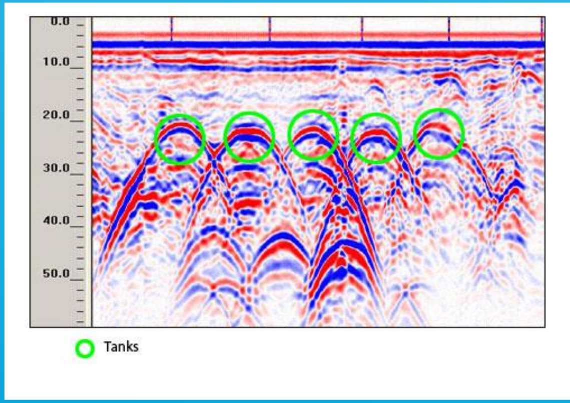
- **Highway 90 from Highway 609 in Ocean Springs, MS to Dolphin Drive in Gautier, MS. Scope included locating all utilities from right of way to right of way. The project included a total distance of 10.2 miles.**

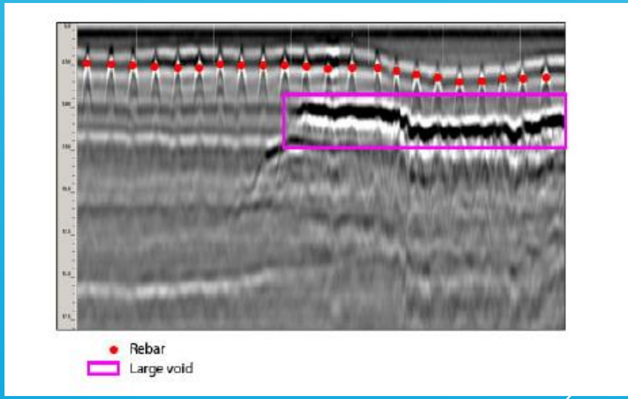
- **A detailed utility survey map was developed for MDOT with the alignments of the utilities located.**

- **In addition to GPR, other SUE tools were used in order to provide a thorough investigation of the area of interest. Level A work was completed to identify unknown utilities**

PRACTICAL APPLICATIONS OF GPR TECHNOLOGY

- **GPR can be used with good results on airport, railroad, building construction, military applications, sanitation, and public works projects where underground utilities may be encountered.**
- **Excellent tool for forensic and failure investigations.**
- **Detection of voids under floor slabs and foundations**
- **GPR can also be used for environmental purposes for detecting and mapping underground storage tanks, septic fields, and contaminants.**





CLOSING COMMENTS

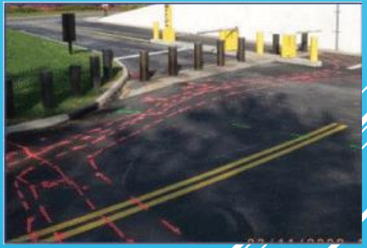
- GPR is a versatile tool

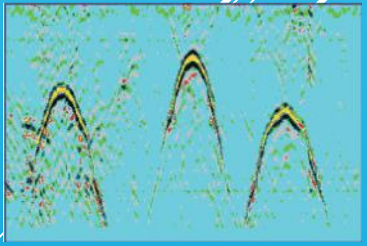
- High level of coordination and communication needed between field utility location staff and surveyors.

- Improper use of technology or inexperienced personnel will result in unsatisfactory outcomes.

- For SUE Conduct additional searches beyond the utility companies to clear discrepancies between records and subsurface survey. Example: buried tanks etc.

- Educate procurement agencies on use of GPR and geophysics to understand the benefits of the process.





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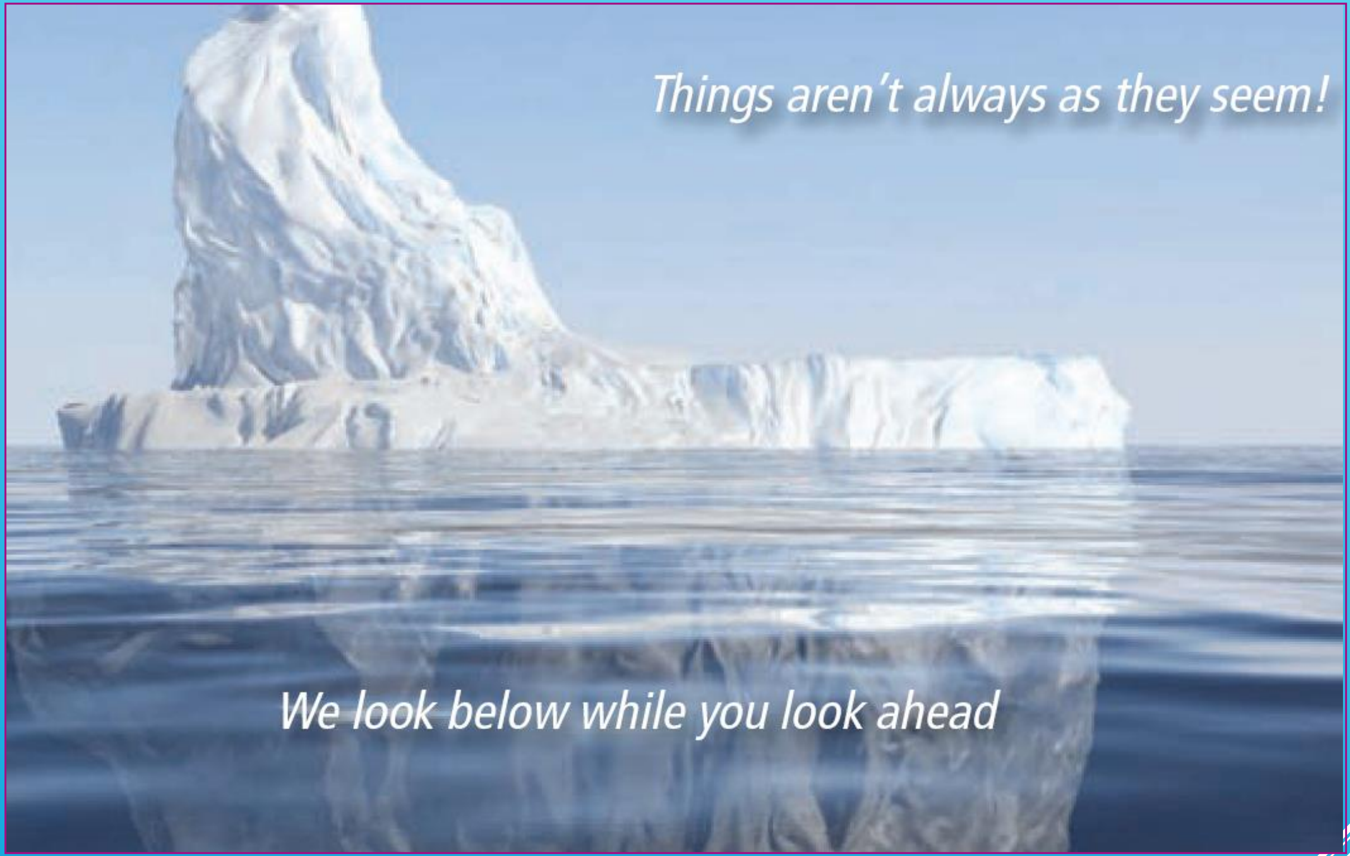
QUESTIONS?



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